ME54B-0920 : Investigating the Effects of Variable Water Type for VIIRS Calibration

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ABSTRACT: The Naval Research Laboratory – Stennis Space Center (NRL-SSC) currently provides calibration and validation support for the Visible Infrared Imaging Radiometer Suite (VIIRS) satellite ocean color products. NRL-SSC utilizes the NASA Ocean Biology Processing Group (OBPG) methodology for on-orbit vicarious calibration with *in situ* data collected in blue ocean water by the Marine Optical Buoy (MOBY). An acceptable calibration consists of 20-40 satellite to in situ matchups that establish the radiance correlation at specific points within the operating range of the VIIRS instrument. While the current method improves the VIIRS performance, the MOBY data alone does not represent the full range of radiance values seen in the coastal oceans. We will utilize data from the AERONET-OC coastal sites to expand our calibration matchups to cover a more realistic range of continuous values (nLw) particularly in the green and red spectral regions of the sensor. Improved calibration will provide more accurate data to support daily operations and enable construction of valid climatology for future reference.

CALIBRATION BACKGROUND:

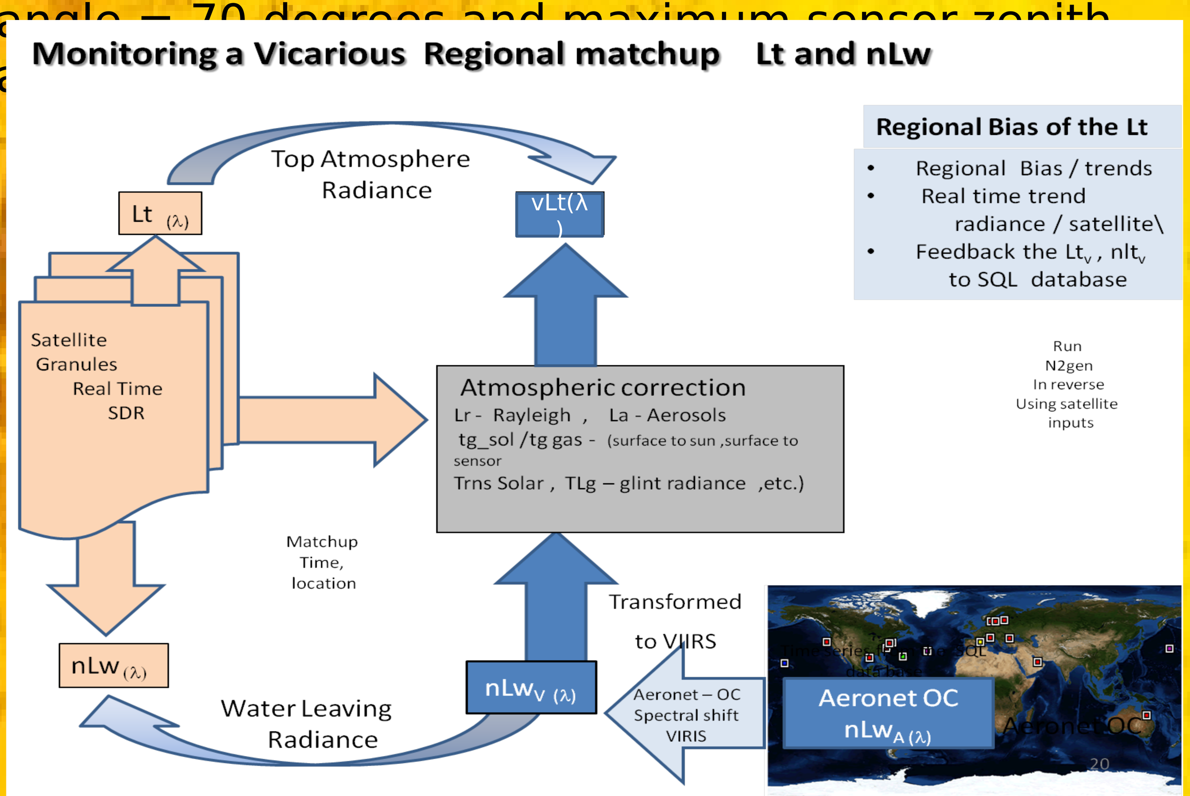
(Franz et. al, 2007, Werdell et al 2007).

Extensively published by NASA's Ocean Biology Program Group (OBPG), the vicarious calibration is an inversion of the forward processing algorithm resulting in a ratio of predicted (vLt) to observed TOA radiance (Lt).

$$\text{gain}(\lambda) = vLt(\lambda) / Lt(\lambda)$$

Satellite constraints: within ±3 hours of over pass and **no** flags allowed on satellite imagery

Exclusion criteria: wind speed must be less than 8 m/s, the maximum aerosol optical thickness (AOT) must be less than 0.2, the nLw values must be between 0.001 and 3.0, the maximum solar zenith angle = 70 degrees and maximum sensor zenith a

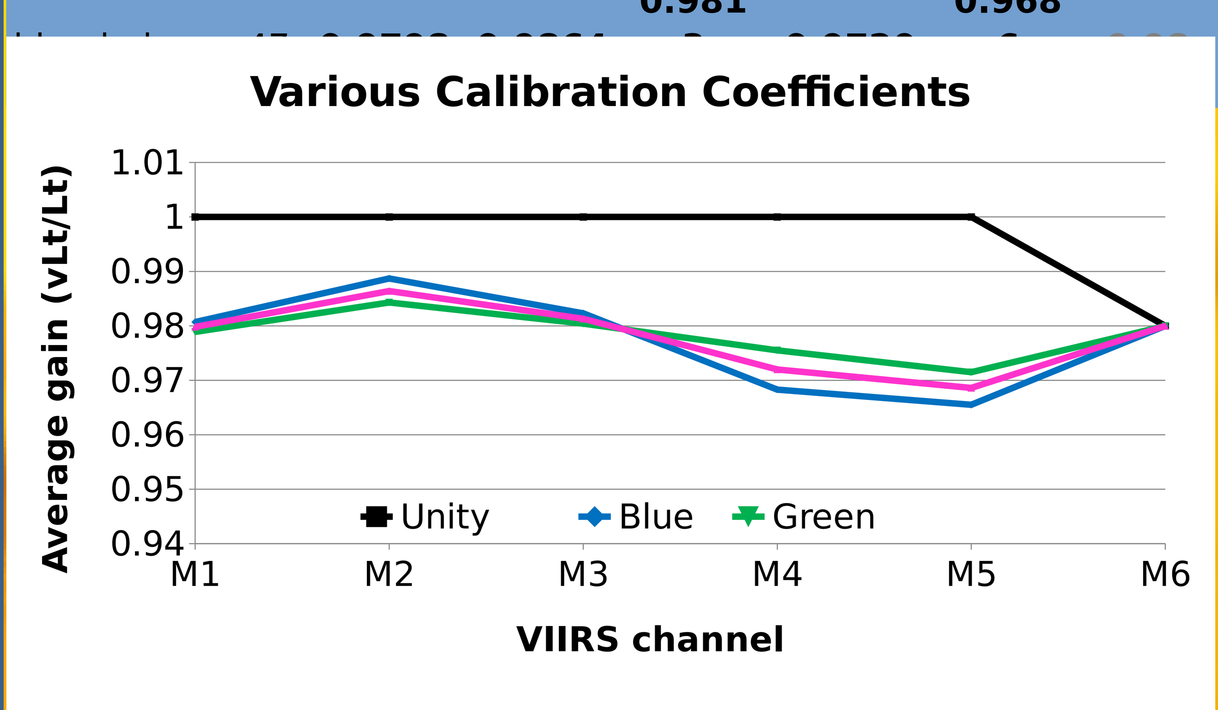


STEP 1:

Following the NASA OBPG orbit calibration technique derive calibration coefficients using satellite: in situ matchups:

- The blue gain is comprised of 23 matchups from the MOBY site collected between June 2014 and Feb 2015.
- The green gain is derived from 24 matchups from the Venice (18) and Gulf of Mexico (6) AERONET-Ocean Color sites between June 2014 and August 2015.
- The blended gain derived from 47 matchups from MOBY (23), Venice (18) and Gulf of Mexico (6).

Calibration coefficients	M1	M2	M3	M4	M5	M6
Unity	1	1	1	1	1	0.98
blue, n = 23	**0.9807**	**0.9887**	**0.9823**	**0.9683**	**0.9655**	0.98
blue stdev	0.0105	0.0090	0.0079	0.0066	0.0062	
green, n = 24	**0.9789**	**0.9843**	**0.9804**	**0.9755**	**0.9715**	0.98
green stdev	0.0130	0.0112	0.0116	0.0132	0.0134	
blended, n = 47	[illegible]	[illegible]	**0.981**[illegible]	[illegible]	**0.968**[illegible]	[illegible]



STEP 2:

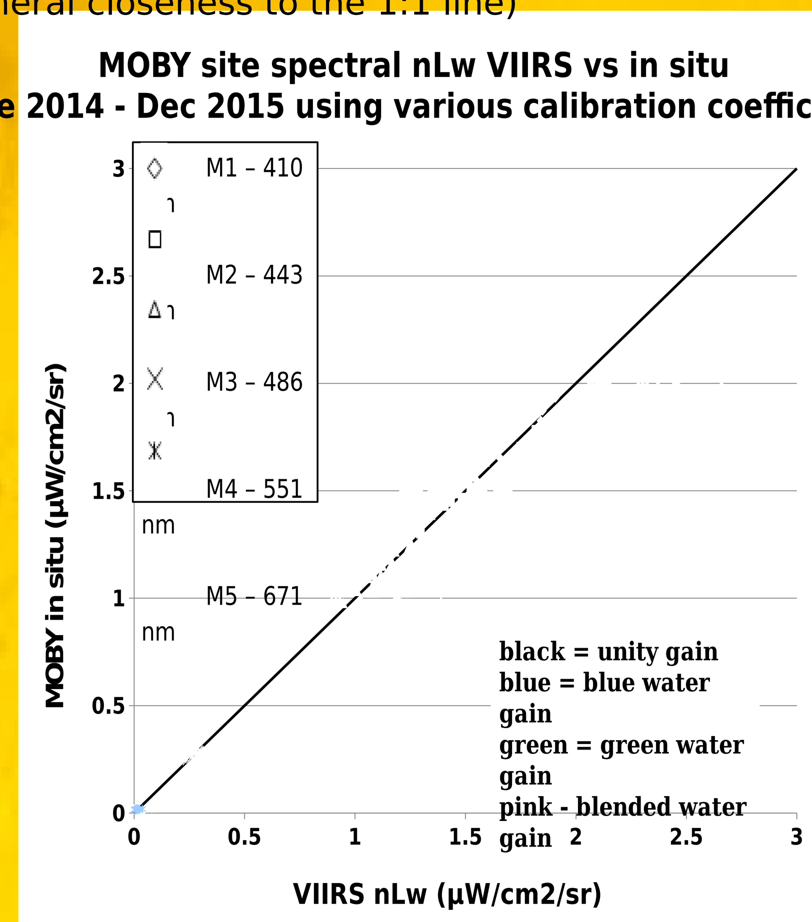
Use NRL Automated Processing System (APS) to process satellite imagery collected between June 2014 and December 2015 *(post Delta-c)* at the blue water MOBY site and the green water AERONET sites: WCIS (Gulf of Mexico) and Venise (Italy).

STEP 3:

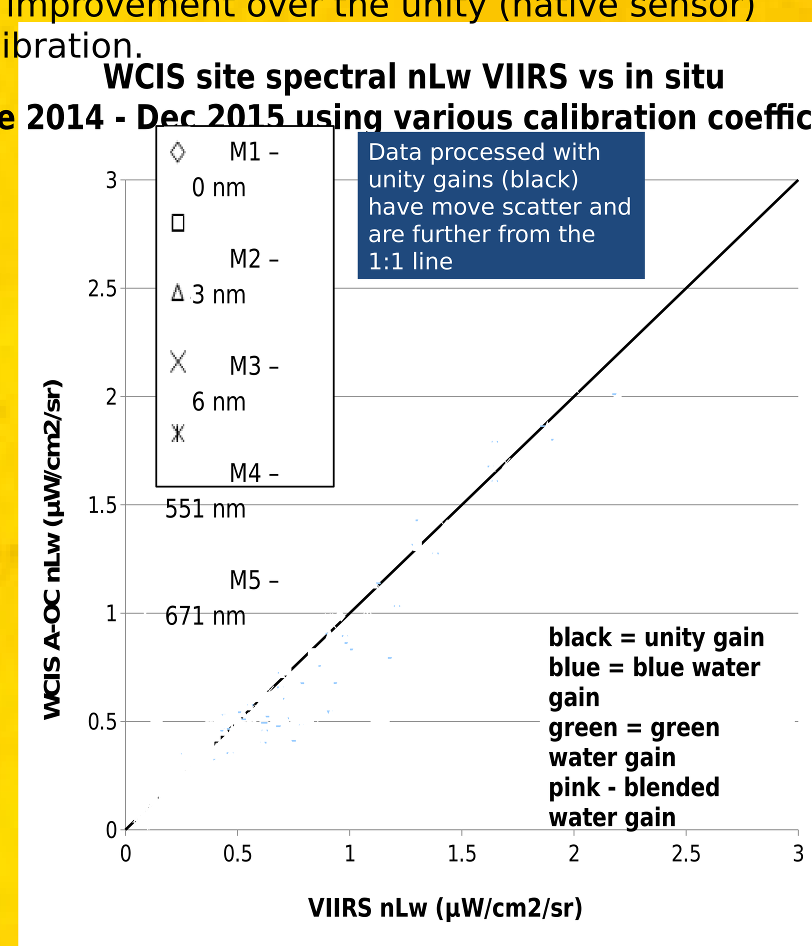
Aggregate satellite and in situ matchups within 3 hours of satellite overpass, with a solar zenith angle <70, and sensor zenith angle <56 degrees. Remove matchups with atmospheric

STEP 4: employ regression analysis

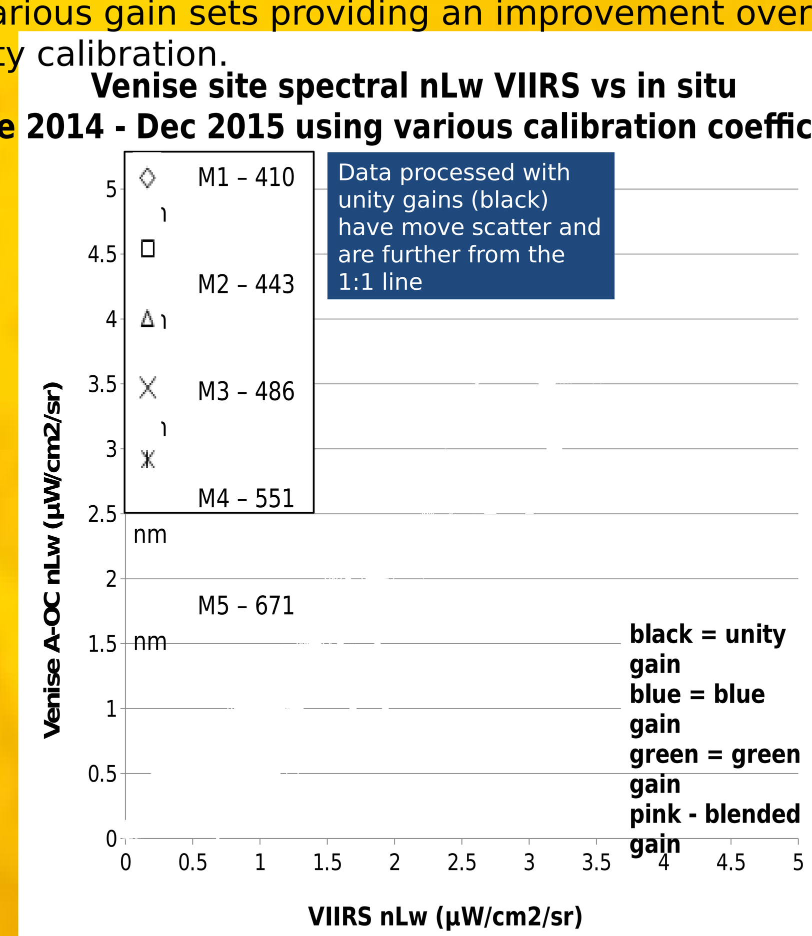
For the MOBY site, all calibrations produce more accurate retrievals than using the unity gain, (note the general closeness to the 1:1 line)



At the WCIS site, all vicarious calibration sets also are an improvement over the unity (native sensor) calibration.



The results hold true at the Venise site as well, with all vicarious gain sets providing an improvement over the unity calibration.



STEP 5: generate traditional statistics

The statistics are comparable for all 3 sites with slight performance variations between the calibration coefficients

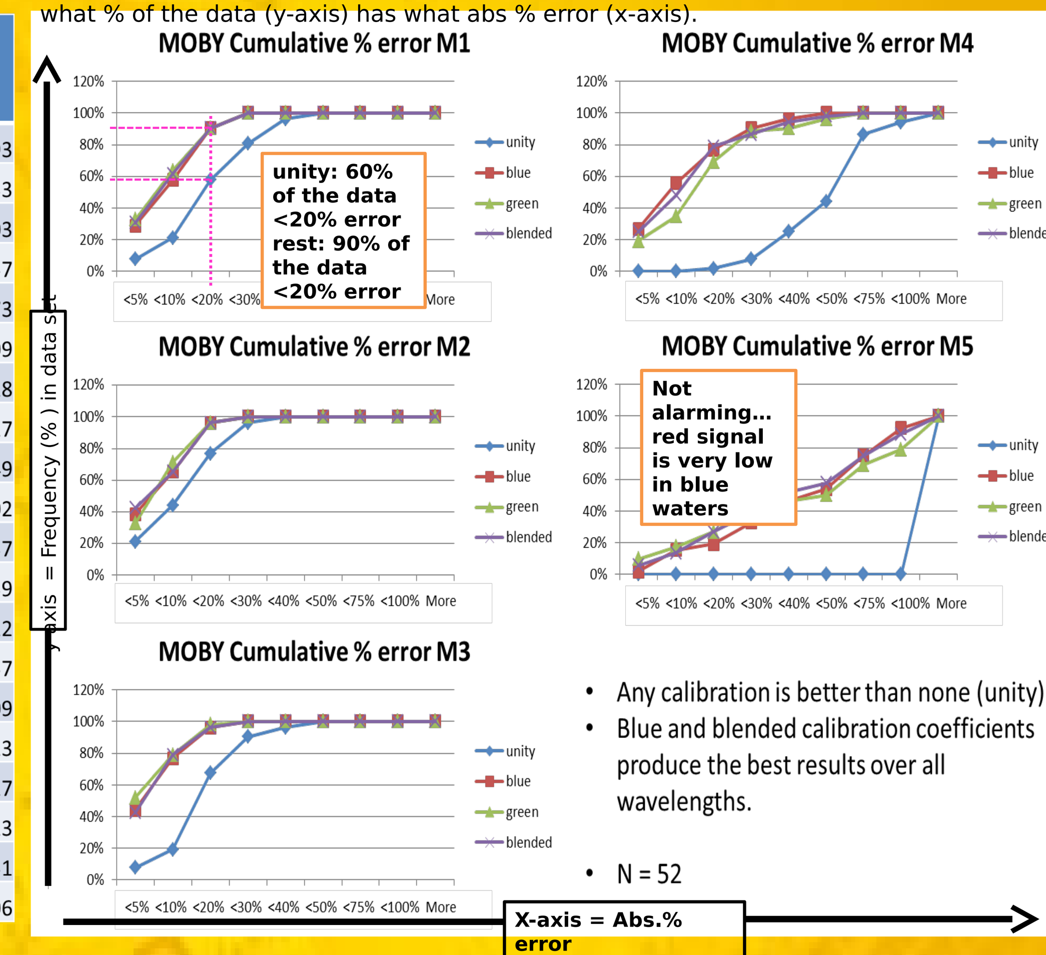
MOBY, n= 52		VIIRS range	In situ range	Slope, r^2	Median ratio	Median Abs%diff	RMSE
UNITY	M1	(1.366, 3.015)	(1.271, 2.445)	(1.2, 0.993)	1.182	18.2	0.193
	M2	(1.156, 2.321)	(1.136, 1.971)	(1.13, 0.994)	1.111	11.1	0.1433
	M3	(0.999, 1.63)	(0.945, 1.334)	(1.166, 0.994)	1.164	16.4	0.103
	M4	(0.319 ,0.539)	(0.223, 0.304)	(1.557, 0.982)	1.566	56.6	0.057
	M5	(0.041, 0.102)	(0.014, 0.02)	(3.969, 0.942)	3.761	276.1	0.0173
BLUE WATER CALIBRATION	M1	(1.047, 2.65)	(1.271, 2.445)	(1.04, 0.99)	1.032	7.1	0.2009
	M2	(1.044, 2.147)	(1.136, 1.971)	(1.046, 0.993)	1.03	7.1	0.1418
	M3	(0.875, 1.459)	(0.945, 1.334)	(1.035, 0.994)	1.024	5.9	0.0917
	M4	(0.129, 0.375)	(0.223, 0.304)	(1.005, 0.974)	1	8.8	0.0449
	M5	(-0.004, 0.038)	(0.014, 0.02)	(0.921, 0.715)	0.807	46.1	0.0102
GREEN WATER CALIBRATION	M1	(0.99, 2.615)	(1.271, 2.445)	(1.021, 0.989)	1.012	8.5	0.2037
	M2	(0.966, 2.087)	(1.136, 1.971)	(1.006, 0.992)	0.995	6.8	0.1439
	M3	(0.86, 1.441)	(0.945, 1.334)	(1.016, 0.994)	1.01	4.9	0.0912
	M4	(0.187, 0.408)	(0.223, 0.304)	(1.131, 0.979)	1.131	13.3	0.0457
	M5	(0.005, 0.048)	(0.014, 0.02)	(1.448, 0.845)	1.39	47.6	0.0109
BLENDED WATER CALIBRATION	M1	(1.019, 2.632)	(1.271, 2.445)	(1.03, 0.989)	1.022	7.9	0.2023
	M2	(1.016, 2.116)	(1.136, 1.971)	(1.025, 0.992)	1.011	7.7	0.1427
	M3	(0.867, 1.449)	(0.945, 1.334)	(1.025, 0.994)	1.017	5.4	0.0913
	M4	(0.159, 0.389)	(0.223, 0.304)	(1.07, 0.977)	1.058	10.3	0.0451
	M5	(0.001, 0.043)	(0.014, 0.02)	(1.189, 0.797)	1.118	38.5	0.0106

WCIS, n= 81		VIIRS range	In situ range	Slope, r^2	Median ratio	Median Abs%diff	RMSE
UNITY	M1	(0.161, 1.636)	(0.078, 0.985)	(1.774, 0.805)	2.419	141.9	0.3204
	M2	(0.251, 1.712)	(0.149, 1.387)	(1.369, 0.898)	1.622	62.2	0.2403
	M3	(0.377, 2.38)	(0.241, 2.011)	(1.284, 0.957)	1.497	49.7	0.2027
	M4	(0.43, 2.478)	(0.264, 2.239)	(1.228, 0.974)	1.366	36.6	0.1757
	M5	(0.101, 0.729)	(0.022, 0.528)	(1.496, 0.929)	1.772	77.2	0.0802
BLUE WATER CALIBRATION	M1	(0.064, 1.244)	(0.078, 0.985)	(1.07, 0.806)	1.14	33.8	0.1955
	M2	(0.147, 1.538)	(0.149, 1.387)	(1.057, 0.898)	1.155	22.9	0.1937
	M3	(0.22, 2.198)	(0.241, 2.011)	(1.078, 0.975)	1.14	16.5	0.1304
	M4	(0.282, 2.262)	(0.264, 2.239)	(1.032, 0.986)	1.047	9.4	0.1075
	M5	(0.04, 0.565)	(0.022, 0.528)	(1.084, 0.957)	1.12	17.3	0.0462
GREEN WATER CALIBRATION	M1	(0.071, 1.223)	(0.078, 0.985)	(1.075, 0.815)	1.155	30.9	0.1889
	M2	(0.131, 1.501)	(0.149, 1.387)	(1.061, 0.924)	1.103	20.8	0.1596
	M3	(0.225, 2.185)	(0.241, 2.011)	(1.081, 0.975)	1.15	16.5	0.1286
	M4	(0.31, 2.307)	(0.264, 2.239)	(1.079, 0.984)	1.11	11.8	0.1207
	M5	(0.055, 0.581)	(0.022, 0.528)	(1.194, 0.959)	1.227	22.7	0.0479
BLENDED WATER CALIBRATION	M1	(0.067, 1.233)	(0.078, 0.985)	(1.07, 0.811)	1.148	33	0.1923
	M2	(0.137, 1.519)	(0.149, 1.387)	(1.033, 0.9)	1.112	20.1	0.1871
	M3	(0.222, 2.191)	(0.241, 2.011)	(1.077, 0.975)	1.13	15.6	0.1297
	M4	(0.296, 2.285)	(0.264, 2.239)	(1.055, 0.986)	1.075	8.5	0.1136
	M5	(0.047, 0.574)	(0.022, 0.528)	(1.123, 0.954)	1.164	18.6	0.0496

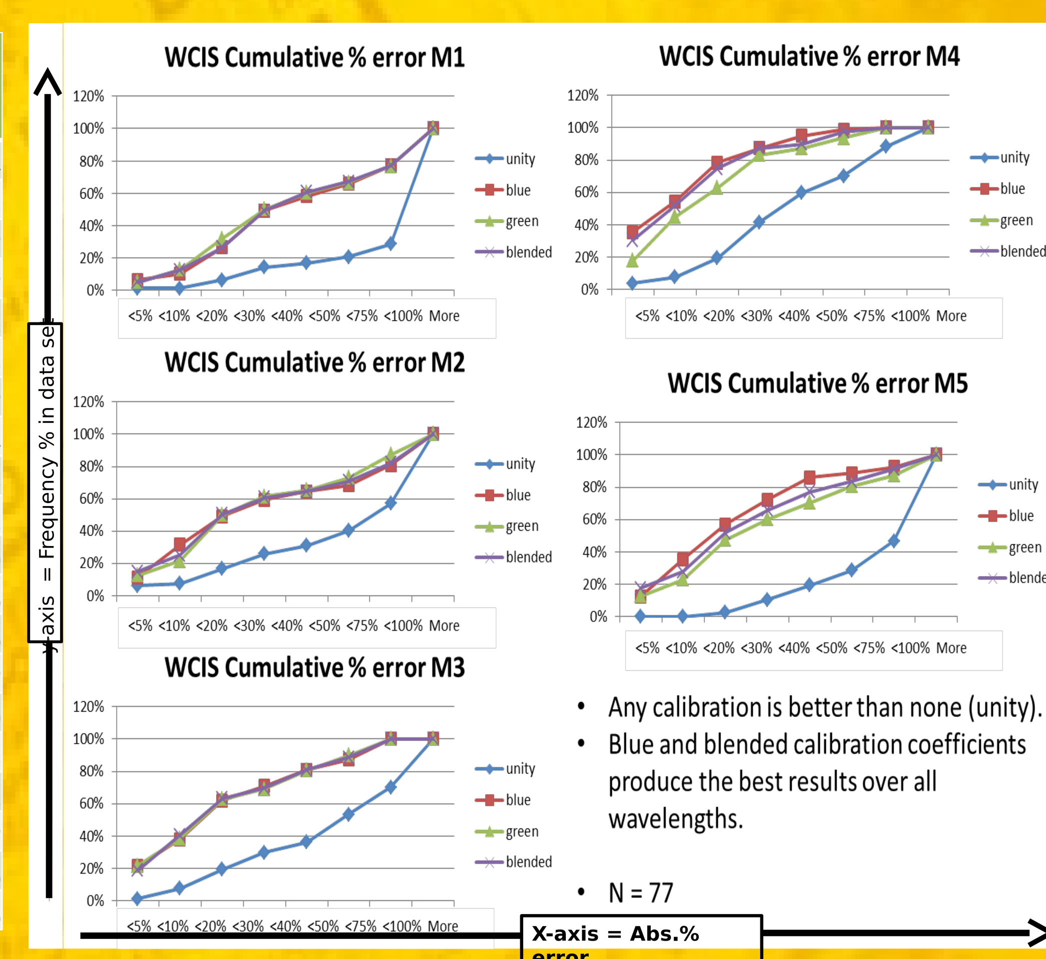
VENISE, n= 157		VIIRS range	In situ range	Slope, r^2	Median ratio	Median Abs%diff	RMSE
UNITY	M1	(0.323, 3.467)	(0.19, 2.61)	(1.418, 0.897)	1.596	59.558	0.3961
	M2	(0.361, 3.563)	(0.222, 3.5)	(1.223, 0.952)	1.327	32.736	0.2961
	M3	(0.488, 4.521)	(0.379, 4.601)	(1.138, 0.979)	1.201	20.068	0.238
	M4	(0.463, 4.809)	(0.414, 4.817)	(1.118, 0.985)	1.21	20.974	0.1957
	M5	(0.042, 1.708)	(0.024, 1.171)	(1.284, 0.937)	1.51	50.966	0.0864
BLUE WATER CALIBRATION	M1	(0.112, 2.749)	(0.19, 2.61)	(1.002, 0.895)	1.048	20.327	0.2823
	M2	(0.245, 3.213)	(0.222, 3.5)	(1.049, 0.96)	1.082	14.995	0.2293
	M3	(0.353, 4.173)	(0.379, 4.601)	(0.996, 0.986)	0.996	9.628	0.1719
	M4	(0.331, 4.421)	(0.414, 4.817)	(0.965, 0.991)	0.965	7.911	0.1272
	M5	(-0.037, 1.465)	(0.024, 1.171)	(0.967, 0.951)	0.864	23.48	0.057
GREEN WATER CALIBRATION	M1	(0.146, 2.713)	(0.19, 2.61)	(0.996, 0.9)	1.037	21.195	0.2725
	M2	(0.242, 3.161)	(0.222, 3.5)	(1.016, 0.962)	1.03	14.83	0.2167
	M3	(0.345, 4.155)	(0.379, 4.601)	(0.992, 0.986)	0.993	9.384	0.1686
	M4	(0.356, 4.498)	(0.414, 4.817)	(0.999, 0.991)	1.015	7.514	0.1341
	M5	(-0.013, 1.502)	(0.024, 1.171)	(1.029, 0.957)	0.975	19.881	0.0566
BLENDED WATER CALIBRATION	M1	(0.128, 2.731)	(0.19, 2.61)	(0.998, 0.898)	1.042	20.593	0.2769
	M2	(0.242, 3.186)	(0.222, 3.5)	(1.031, 0.961)	1.056	14.302	0.2223
	M3	(0.352, 4.163)	(0.379, 4.601)	(0.993, 0.986)	0.996	9.889	0.1698
	M4	(0.345, 4.46)	(0.414, 4.817)	(0.983, 0.991)	0.994	7.365	0.1298
	M5	(-0.026, 1.485)	(0.024, 1.171)	(0.999, 0.955)	0.905	19.773	0.0563

STEP 6: look at distribution of error

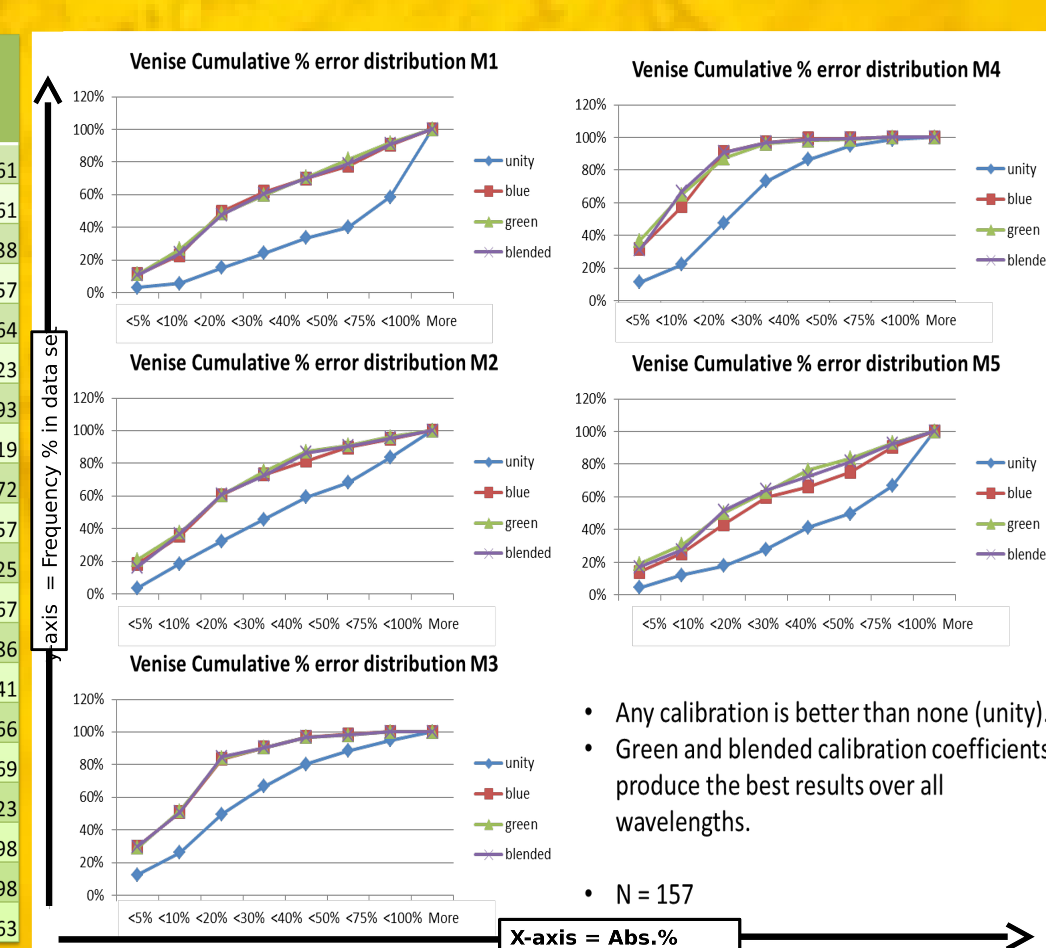
Here we use a quality control procedure called Pareto Analysis which shows the relative frequency of error distribution. Normally, a Pareto chart has 2 parts: a bar graph and frequency distribution curve. For brevity we compare the cumulative frequency curves where we have normalized the abs % error to the total number of matchups, telling us what % of the data (y-axis) has what abs % error (x-axis).



- Any calibration is better than none (unity).
- Blue and blended calibration coefficients produce the best results over all wavelengths.
- N = 52



- Any calibration is better than none (unity).
- Blue and blended calibration coefficients produce the best results over all wavelengths.
- N = 77



- Any calibration is better than none (unity).
- Green and blended calibration coefficients produce the best results over all wavelengths.
- N = 157

CONCLUSIONS:

- The OBPG standard methodology using MOBY data provides the most stable calibration (*note, lowest stdev*).
- In the absence of sufficient quality MOBY matchups we can supplement the blue water matchups with high quality AERONET-OC green water matchups without significantly affecting the error distribution of nLw retrievals.
- This methodology can be used to support real-time operations and speed up the transition process for new sensors coming online.

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